



Sound Production Treatment: Application with severe apraxia of speech

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Background: Acquired apraxia of speech (AOS) has been shown to be responsive to behavioural intervention. Although numerous treatments for AOS have been developed, most have received limited study. Specifically, the AOS treatment evidence base is compromised by a lack of replication of treatment effects. Sound Production Treatment (SPT; Wambaugh, Kalinyak-Fliszar, West, & Doyle, 1998) has undergone more systematic examination than other AOS treatments and has been documented to result in predictable improvements in consonant production. However, SPT has not been studied with persons with severe AOS and perseverative speech behaviours.

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Aims: The purpose of this investigation was to examine the acquisition, response generalisation, and maintenance effects of SPT with a speaker with severe AOS, significant nonfluent aphasia, and verbal perseverations.

Methods & Procedures: A single-participant, multiple baseline design across behaviours was employed to examine the effects of treatment on production of six consonants in monosyllabic words. Treatment was applied sequentially to two sets of items, with three consonants targeted in each set. A third phase of treatment entailed training of all target sounds. Follow-up probing was conducted at 10 and 15 weeks post-treatment.

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Outcomes & Results: Improved productions were observed for all trained items and response generalisation to untrained exemplars of trained items was positive. Across-sound generalisation was not evident. Maintenance effects were strong at 10 weeks post-treatment, but diminished considerably for most of the sounds by 15 weeks.

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Conclusions: Results for this speaker with severe AOS and verbal perseverations were similar to those previously reported for SPT. The decrease in performance from 10 weeks to 15 weeks indicated that changes in behaviour had not been sufficiently instantiated. Furthermore, these findings suggested that maintenance probing may need to be conducted over a considerably longer period of time than has previously been reported in the literature.

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Keywords: Apraxia of speech; Aphasia; Treatment.

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Acquired apraxia of speech (AOS) is a neurologic speech disorder that is character-
 ised by slowed rate of speech, difficulties in sound production, and disrupted pros-
 ody (McNeil, Robin, & Schmidt, 2009). A critical review of the AOS treatment

literature by the Academy of Neurologic Communication Disorders and Sciences
 (ANCDS) AOS guidelines committee indicated that although the evidence base for
 AOS treatment was relatively sparse and lacking in many respects, there was suffi-
 cient support for the statement that “individuals with AOS can be expected to make
 improvements in speech production as a result of treatment, even when AOS is
 chronic” (Wambaugh, Duffy, McNeil, Robin, & Rogers, 2006, p. lxiii). 40 45

Various treatments for AOS may result in improved speech production, but there
 is a limited understanding of the effects of specific techniques or treatment factors
 that contribute to positive changes (Wambaugh et al., 2006). In fact, in order to
 provide qualitative ratings of the AOS treatment evidence, the ANCDS AOS guide-
 lines committee grouped treatment investigations by “general approach” because
 there was insufficient evidence for any one treatment/technique (Wambaugh et al.,
 2006). 50

Of the general approaches to AOS treatment, articulatory-kinematic approaches
 have received the most study (Wambaugh et al., 2006). Such approaches are designed
 to increase the accuracy of the speaker’s production of sounds through improve-
 ments in the movement and/or positioning of the articulators. Techniques that are
 considered to be articulatory-kinematic in nature include integral stimulation (i.e.,
 “watch me, listen to me, say it with me”), modelling-repetition, articulatory
 placement instructions, repeated practice, feedback concerning articulation (e.g., ver-
 bal feedback, biofeedback), contrastive practice, shaping, and tactile-kinaesthetic
 cueing. 60

Sound Production Treatment (SPT) is an articulatory-kinematic treatment for
 AOS that combines modelling-repetition, minimal contrast practice, integral stimu-
 lation, articulatory placement cueing, repeated practice, and verbal feedback
 (Wambaugh et al., 1998). Additionally, it incorporates aspects of principles of motor
 learning (Maas et al., 2008) such as blocked and random practice and a reduced feed-
 back schedule. SPT has received more extensive and systematic study than any other
 specific treatment for AOS (Duffy, 2005; Wambaugh, 2002). Although much
 remains to be specified concerning SPT and its application, its acquisition, response
 generalisation, and maintenance effects have been demonstrated to be robust and
 relatively predictable. SPT has been shown to improve articulatory accuracy of
 consonant production in words, phrases, and sentences for trained and untrained
 items (Wambaugh, 2004; Wambaugh & Nessler, 2004). To date, the effects of SPT
 have not been studied with persons with severe AOS who have extremely limited
 sound repertoires. Furthermore, it has not been studied in speakers with significant
 verbal motor perseveration. 70 75

It was considered that aspects of SPT such as integral stimulation and articulatory
 placement cueing should promote differentiated consonant production with AOS
 speakers with limited sound production capabilities. Given that perseveration may
 result from reduced speech/language processing efficiency (Moses, Nickels, &
 Sheard, 2007), it was further speculated that treatment focused on facilitating speech
 production would be appropriate even in the presence of significant perseveration.
 Furthermore, aspects of the treatment such as minimal contrast practice and random
 practice of multiple sounds was thought to have potential benefit if competing
 activation was a source of perseverative behaviour. 80 85



As indicated in the ANCDs AOS guidelines report, one of the biggest liabilities of the AOS treatment evidence base is a lack of replications of treatment effects

(Wambaugh et al., 2006). The purpose of this investigation was to conduct a systematic replication of the effects of SPT with a speaker with more severe deficits than previously studied participants. Specifically, the investigation was designed to examine the acquisition, response generalisation, and maintenance effects of SPT in an individual with severe AOS, verbal motor perseverations, and stereotypic productions.

METHOD

Participant

The participant was a 55-year-old Caucasian male who was 2 years post-onset of a left CVA. Radiological reports indicated a large cortical lesion involving the entire distribution of the middle cerebral artery. The participant was a native-English speaker, passed a pure-tone hearing screening at 40dB for each ear, and had hemiparesis of the right leg and arm. He was a retired wood-worker with 14 years of formal education. Additional demographic data are shown in Table 1.

Pre-treatment assessment findings are presented in Table 2. The participant attained a *Porch Index of Communicative Abilities* (PICA; Porch, 2001) overall percentile score of 19 and a *Western Aphasia Battery* aphasia quotient (WAB AQ; Kertesz, 1982) of 14.8 Performance on the WAB was consistent with a classification of Broca’s aphasia.

The participant presented with severe AOS, with speech behaviours that were consistent with diagnostic criteria described by McNeil et al. (2009): (1) sound errors that were predominantly distortions, (2) errors that were consistent in terms of location and type, (3) slow rate of speech production, and (4) disrupted prosody. His spontaneous, verbal productions were extremely limited and reflected a very restricted sound repertoire, consisting primarily of /w, h, d, a, n, h, o, j, / . He combined these sounds in various ways with some combinations being stereotypic in nature (e.g., /w ha ə/). He often perseverated on these stereotypic productions.

An evaluation of the participant’s consonant production in monosyllabic words (five exemplars of all English consonants in word-initial and word-final positions) revealed that only word-initial /w/ and /n/ were produced accurately on a consistent basis (i.e., >50% accuracy). Examples of the participant’s errors in response to the monosyllabic word repetition task are provided in Appendix A.

TABLE 1
Participant demographic information

Characteristic	Participant
Gender	male
Age	55
Months post-onset CVA	24
Area of infarct	left cortex – entire middle cerebral artery distribution
Years of education	14
Premorbid handedness	right
Marital status	married
Residence	own home
Former profession	wood-worker



<i>Measure</i>	<i>Performance</i>
Porch Index of Communicative Ability (Porch, 2001)	
Overall Percentile	19th
Verbal Percentile	11th
Auditory Percentile	21st
Western Aphasia Battery (Kertesz, 1982)	
Aphasia Quotient	14.8
Aphasia Classification	Broca's Aphasia
Raven's Coloured Progressive Matrices (Raven, Raven, & Court, 2003)	26/36
Assessment of Intelligibility of Dysarthric Speech (Yorkston & Beukelman, 1981)	
Word Intelligibility (multiple choice)	0%
AOS Behaviours	
Sound errors	predominately distortions
Consistent location and type of errors	yes
Slow rate of production	yes
Disrupted prosody	yes

The participant was originally recruited to participate in a rate control treatment study, but was unable to demonstrate the minimal repetition skills necessary for inclusion in that investigation. He did not participate in any other speech/language therapy at the time of the investigation. According to his family, one of his early speech/language experiences involved working exclusively on the phrase, "I want water." His errors and stereotypic productions appeared to be closely related to this phrase (see Appendix A). 120

Experimental stimuli 125

Six sounds were selected for treatment and were grouped into two sets of three sounds each: Set 1 = /b, s, l/, and Set 2 = /m, d, f/. Manner and place of production were considered in the selection and grouping of experimental sounds. The targeted sounds were elicited in the context of monosyllabic, real words with either CV or CVC shapes. A total of 13 words were selected for each sound; 8 words were used for treatment and 5 words were untreated in order to assess response generalisation (see Appendix B). 130

The experimental words were also selected so that minimal pair items could be devised to be used during treatment. Because the participant most often produced a variant of "water" for all items, the minimal pair items were all word-initial /w/ words (e.g., target item = buy, minimal pair item = why; target item = say, minimal pair item = way). 135

Experimental design

A multiple baseline design across behaviours was used to examine the acquisition and response generalisation effects of treatment. Production of the six consonants in the context of monosyllabic words was measured repeatedly in baseline probes. 140



Treatment was then applied to three of the six sounds, while the other three sounds remained untreated. Following 25 treatment sessions, treatment was withdrawn from the first three sounds and extended to the remaining three sounds. After the second phase of treatment, treatment was applied to all six sounds simultaneously.

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Baseline phase. Five probes were conducted during the initial baseline phase for all six sounds of interest. A minimum of five probes was selected a priori to allow adequate evaluation of variability. An additional criterion of non-rising trends for all groups of sounds (trained and generalisation items) was employed to determine baseline length.

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Each set of items representing three target sounds was presented as a group. The 39 items (8 treatment and 5 generalisation items for each of the 3 sounds) were randomised and presented verbally, one at a time. The investigator instructed the participant to produce each word as well as he could. A single repetition of the item by the examiner was provided upon request of the participant. The order of presentation of the two sets of items was randomised for each probe session.

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Treatment phase. During the first two treatment phases, the set of items receiving treatment was probed every session, while the set not receiving treatment was probed after every five treatment sessions. During the final treatment phase, probes were conducted after every two treatment sessions for all sounds. This change in probing schedule was due to the treatment time (per session) being slightly extended because all six sounds were receiving treatment. Probes were always conducted prior to treatment. During probes (baseline and treatment phases), no feedback regarding accuracy of articulation was provided. General encouragers (e.g., “you’re trying hard”) were given.

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Follow-up phase. Follow-up probes were conducted at 10 and 15 weeks after the cessation of all treatment. Probes had originally been planned for 2 and 6 weeks post-treatment, but health issues prohibited this (described further in Discussion).

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Dependent variable

Accuracy of articulation of the target sounds produced in the experimental words during probes served as the dependent variable. In cases where the participant self-corrected, the self-correction was scored. The participant’s productions were scored for accuracy of consonant production using binary (+/–) scoring. That is, only the target consonant was required to be produced accurately to receive a score of “correct”. Productions were scored online, with audio recordings used to verify scoring. Percentage of correct productions was calculated for each of the sounds, with separate percentages calculated for treatment and for generalisation items.

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Reliability

A total of 10% of all probes were rescored by the investigator who did not conduct and perform the original scoring of the probe. Point-to-point agreement for scoring of each item was calculated and ranged from 92% to 100%, with an average of 96%.

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Treatment was applied in the form of a response contingent hierarchy. Specifically, the steps of the hierarchy were applied only as needed (i.e., in the event of a preceding incorrect response). The treatment hierarchy is shown in Appendix C and includes the following techniques: modelling-repetition, minimal contrast practice, graphemic cueing, integral stimulation, articulatory placement cueing, repeated practice, and verbal feedback. In the first two treatment phases (treatment of Sets 1 and 2 separately), application of the treatment hierarchy to each of the 24 treatment words constituted one treatment trial. Three to four treatment trials were completed in each treatment session when three sounds were under treatment. In the final phase of treatment, when all six sounds received treatment, a trial consisted of application of treatment to each of the 48 treatment words and two trials were completed each session.

Treatment was administered by an ASHA certified speech/language pathologist (i.e., the authors) three times per week. Sessions were approximately 45 to 60 minutes in length, including the probe, during the first two treatment phases. Sessions were approximately 60 minutes in length during the third treatment phase. Therapy was conducted in the research lab or the participant's home, at the preference of the participant and his family.

RESULTS

Probe data, reflecting acquisition and generalisation effects of treatment, are shown in Figure 1. Across the five baseline probes, accuracy of production ranged from 0% to 25% correct with *average* percentages of accuracy as follows: /b/ 3%, /s/ 0%, /l/ 5%, /m/ 10%, /d/ 0%, /f/ 0%.

Following application of treatment to the first group of sounds (/b, s, l/), increases in accuracy of production of /b/ and /l/ were observed. These increases were seen for both trained and untrained items. Changes in accuracy of /s/ production were not observed until the last two probe sessions. During training of the first group of sounds, no changes were observed for the untrained sounds /d/ and /f/. Slight but unstable increases were seen for untrained /m/ during this period.

As seen in Figure 1, when treatment was applied to the second group of sounds (/m, d, f/), increases in accuracy of production were seen for all three sounds for trained and untrained items. Maintenance of the previously trained set of sounds was measured after every fifth treatment session during training of the second set. Production of trained and untrained /b/ remained at high levels as did production of /l/ for most of the second treatment phase. However, accuracy levels of /l/ appeared to be declining by the end of the phase. Productions of /s/ remained at low accuracy levels during training of the second set of sounds.

When treatment was applied to all six sounds simultaneously, high levels of accuracy were achieved for /b/, /s/, /d/, and /f/. Some decreases in correct productions were observed for /m/ and /l/ during this training period.

Follow-up probes conducted at 10 weeks post-treatment revealed the following levels of accuracy: /b/ 100%, /s/ 75%, /l/ 100%, /m/ 50%, /d/ 38%, and /f/ 88%. Probes at 15 weeks post-treatment revealed the following accuracy levels: /b/ 37%, /s/ 13%, /l/ 75%, /m/ 0%, /d/ 25%, and /f/ 88%.

Effect sizes were calculated for all sounds; baseline performance was compared to performance during the last phase of treatment. The *d* Index statistics (Bloom,

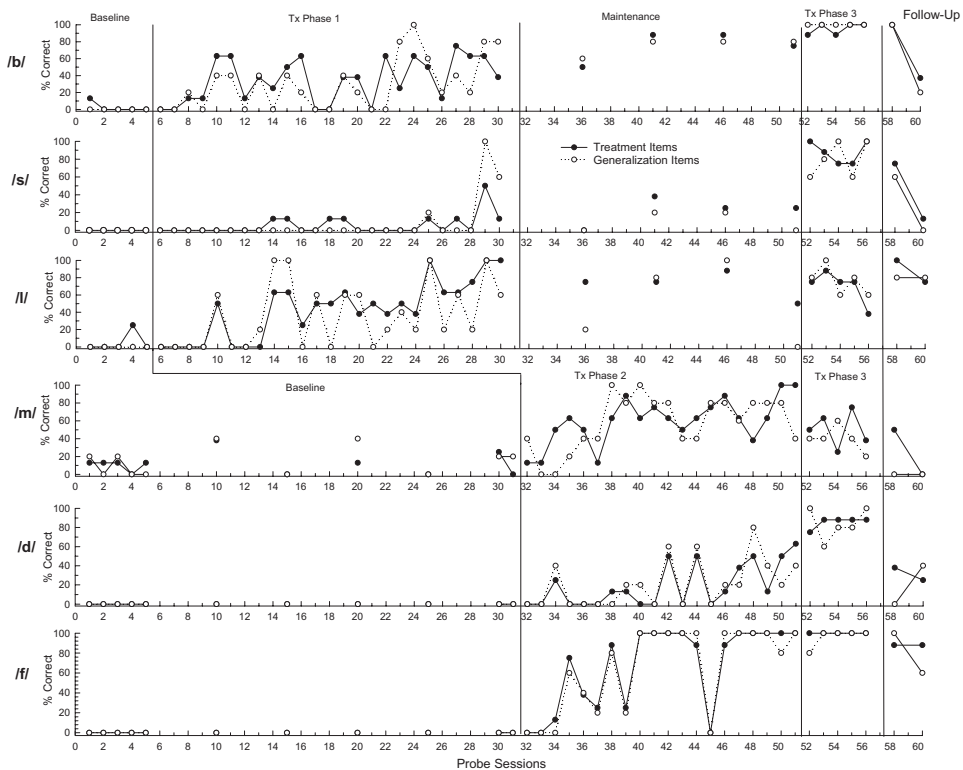


Figure 1. Performance on probes: Accuracy of consonant production.

Fischer, & Orme, 2003) were as follows: b = 14.1; s = 9.89; l = 4.1; m = 2.7; d = 22.29; f >30.9. Additionally, the conservative dual-criteria (CDC; Fisher, Kelley, & Lomas, 2003) method was used as an aid to visual inspection to make a determination of treatment effects. The CDC method has been found to optimally control Type 1 235 error rates even in the presence of high degrees of autocorrelation (Fisher et al.) The CDC procedure entailed creating two criterion lines using the baseline data: a trend line based on the binomial test and a mean line. These criterion lines were both raised by .25 standard deviations and were superimposed on the treatment phases. Interpretation of reliable treatment effects using the CDC method is dependent on a pre- 240 specified number of data points falling above both lines (i.e., 15 of 25 data points, Phase 1; 14 of 20 data points, Phase 2). According to the CDC method, a reliable treatment effect was found for /b/, /l/, /m/, and /f/ during the first application of treatment (Phase 3 was not analysed due to an insufficient number of data points).

DISCUSSION

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Findings were consistent with previous investigations of SPT that involved speakers with less severe AOS and minimal verbal motor perseveration. That is, treatment resulted in improved production of trained sounds in treated words with similar improvements seen for sound production in untreated words. Generalisation to untrained sounds was limited, which is also consistent with previous findings. Probable 250



interference of training sounds with similar place of production was observed during the last phase of training. Specifically, decreasing accuracy of production of /m/ and /l/ were due largely to overgeneralisation of /b/ and /d/, respectively. Similar overgeneralisation has been reported previously with SPT (Wambaugh, Martinez, McNeil, & Rogers, 1999).

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It was somewhat surprising to observe overgeneralisation in the third phase of training when all six sounds were being trained and practised in a random presentation context. Furthermore, all target sounds were practised in varied phonetic contexts. As discussed by Maas et al. (2008), both variable motoric practice and random practice are likely to result generalisation and maintenance of learned behaviours. Furthermore, contrastive practice is consistent with models of speech production/learning that stress the importance of refining target regions through contrastive somatosensory feedback (Guenther, 2006). Currently there are no data concerning the relative merits of variable versus constant practice in the treatment of AOS and limited (albeit promising) data suggesting that random practice is superior to blocked practice (Knock, Ballard, Robin, & Schmidt, 2000).

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In a previous investigation of SPT involving overgeneralisation, “booster treatment” involving training of all sounds simultaneously (as in this investigation) resulted in differentiated sound production that was maintained (Wambaugh et al., 1999). Perhaps the participant in the current investigation was unable to fully utilise somatosensory and auditory feedback from contrastive and random practice to develop clearly differentiated speech sound target regions. Feedback from the clinician focused on differentiating sounds with similar place of production might have been beneficial.

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Guenther and colleagues’ neural model of speech production, “directions into velocities of articulators” (DIVA; Guenther, 2006), indicates that the feedforward commands for speech sounds become tuned by the feedback subsystem in repeated production attempts. Early in the learning process, production relies heavily on the feedback system, but “eventually the feedforward command by itself is sufficient to produce the sound in normal circumstances” (p. 353). The decrease in sound production accuracy observed at 15 weeks post-treatment indicates that the participant’s feedforward commands were insufficiently tuned or instantiated. It is likely that the improved accuracy observed in earlier phases of the study reflected improvements in the feedback control subsystem and that the lengthy period without treatment resulted in a deterioration in that subsystem. Given the presence of overgeneralisation in the last phase of treatment, it may be the case that the somatosensory and/or auditory target regions were not adequately tuned, which theoretically should result in inadequate tuning of the feedforward commands.

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Perhaps treatment should have included specific training to recognise and self-monitor various somatosensory and auditory cues. That is, although feedback was provided concerning accuracy of production and instructions for improving production, this information was completely clinician generated. After the final follow-up probe, informal probes were conducted to assess the participant’s skill in judging accuracy of production. The participant was very accurate in judging correct and incorrect productions made by the therapist, but demonstrated that he had great difficulty in determining if his own productions were accurate or inaccurate. It may be prudent to assess such skills prior to developing a therapy programme. In the case of very poor self-monitoring skills, therapy may need to be modified to include training and application of self-monitoring of auditory and somatosensory feedback.

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As the data clearly show, the participant was able to utilise feedback to modify his 300

productions, but increasing focus or conscious awareness of critical auditory and somatosensory features may have assisted in solidifying feedforward commands for speech sound production. It is possible that additional practice with the same treatment may have been sufficient to promote lasting maintenance of gains. As noted by Ludlow and colleagues (2008, p. s243) in discussing principles of experience-dependent 305 neural plasticity (Kleim & Jones, 2008), “changes in neural substrates will occur only as a result of extensive and prolonged practice and that neural changes may not become consolidated until later in the training process”.

Maintenance of AOS treatment gains has typically not been measured for periods as extended as in the current investigation. Follow-up probes were originally scheduled for 2 and 6 weeks post-treatment. Unfortunately, the participant was hospitalised prior to the first scheduled probe and underwent surgery (not neurological in nature) several weeks later. Although the participant had been provided with “homework” and a practice log, he did not complete any practice during the period from the last treatment session to the 15-week probe. Given the lack of practice and the 315 medical issues, his excellent performance at 10 weeks post-treatment was unexpected. Weather prohibited scheduling another probe for more than a month, which resulted in the 15-week probe. Had these complications not arisen, the decrease in performance at 15 weeks would likely not have been detected. It is suggested that future AOS treatment studies include extended follow-up probes when possible. 320

Another health issue was present during the second phase of treatment. The participant developed mononucleosis, which persisted throughout the second phase of treatment. This did not appear to have an impact on his performance in comparison to the first treatment phase. Despite health issues and the presence of severe AOS, severe aphasia, and verbal perseveration, this participant made impressive 325 gains in consonant production. Unfortunately, verbal motor perseverations and stereotypic productions were not tracked quantitatively. Anecdotally, such behaviours appeared to decrease across the course of treatment. Following completion of this investigation, booster treatment and “homework” have resulted in regaining accuracy levels of production of all sounds and the participant is currently practising 330 production in the context of sentence completion.

Maintenance effects of SPT and other AOS treatments may not be as stable as previously assumed. Modifications to the SPT protocol may be needed to solidify treatment gains. In particular, testing of self-monitoring or and/or awareness of errors and subsequent modifications in SPT may be warranted in future investigations of this treatment. However, the severe nature of this participant’s speech and language deficits may have been the primary factor contributing to less than optimal maintenance. Further replications are obviously warranted. 335

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APPENDIX A

Examples of errors on the word repetition task

- mom → m□d 390
- den → wa□d□lwa□
- beep → ma□ə
- my → ma□
- sigh → w□d□
- sam → o j□s 395
- mow → wa□ə
- bill → bəi□
- bore → j□ə
- four → w□d□

day → w□d□	400
fur → oh□□ə	
food → w□d□	
due → w□d□	
fay → a□ə	
sue → əhe□ə	405
duck → w□d□	
mike → w□d□	

APPENDIX B

Experimental stimuli

<i>Set 1 Items</i>	410
/b/	
Treatment items: buy, bee, bite, bay, bore, beep, ben, bill	
Minimal pair items: why, we, white, way, war, weep, when, will	
Generalisation items: boo, bar, bib, bait, bean	
/s/	415
Treatment items: say, sill, sit, sue, Sam, seal, sew, see	
Minimal pair items: way, will, wit, woo, wham, wheel, whoa, we	
Generalisation items: sigh, sail, sip, saw, sat	
/l/	420
Treatment items: lie, low, lit, lee, lay, lick, line, late	
Minimal pair items: why, who, wit, we, way, wick, wine, wait	
Generalisation items: Lou, law, lane, lead, lip	
<i>Set 2 Items</i>	
/m/	425
Treatment items: may, mow, me, Mike, mat, mom, mail, men	
Minimal pair items: way, whoa, we, wick, what, womb, whale, when	
Generalisation items: my, moo, more, main, mill	
/d/	430
Treatment items: day, due, dog, dear, date, dome, den, dye	
Minimal pair items: way, woo, wag, we're, wait, womb, when, why	
Generalisation items: doll, done, duck, door, dough	
/f/	435
Treatment items: fee, four, fun, foam, fill, fat, food, fay	
Minimal pair items: we, war, one, womb, will, what, wood, way	
Generalisation items: few, phone, fur, foe, fit	

APPENDIX C

Sound Production Treatment hierarchy

- Therapist says word and requests repetition.
 - If correct, request additional repetitions (5 times*) and go to next item.
 - If incorrect, give feedback and say, “Now let’s try a different word” and produce minimal pair word and request a repetition.



- If correct, give feedback and say, “Now let’s go back to the other word” and go to #2 with the target word.
 - If incorrect, give feedback, attempt with integral stimulation up to 3 times, then go to #2 with the target word. 445
2. Therapist shows the printed letter of the target sound, says word, and requests repetition.
 - (a) If correct, request addition repetitions (5 times) and go to the next item.
 - (b) If incorrect, go to #3.
 3. Therapist uses integral stimulation: “Watch me, listen to me, say it with me” up to three times. 450
 - (a) If correct, request addition repetitions (5 times) and go to the next item.
 - (b) If incorrect, go to #4.
 4. Therapist provides verbal articulatory placement cues appropriate to error. Therapist elicits production using integral stimulation.
 - (a) If correct, request addition repetitions (5 times) and go to the next item. 455
 - (b) If incorrect, go to next item.

*Provide feedback for accuracy for approximately 3 of the 5 productions

Note: *the hierarchy is response-contingent (subsequent steps are used only upon incorrect production) and does not reverse directions.*